sustainability

Article

Socioeconomic Impacts of Sustainability Practices in the Production and Use of Carrier Bags

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Abstract: Although the negative environmental impact of plastic carrier bags has long been known, their use in Europe continues undiminished. Lithuania stands out for its high use and production of plastic bags. Governments and sustainability-driven businesses are taking various measures to reduce the environmental impact. Such measures include strategies to replace conventional plastic bags with paper or bioplastic bags, to reduce plastic bags by encouraging consumers to reuse them, and similar strategies. In contrast to the environmental impact of plastic bags, the socioeconomic effects of strategies to reduce their use have been much less studied in the scientific literature. Therefore, this paper analyses the impact of sustainability practices in the producing and using of carrier bags on Lithuania's gross domestic product (GDP), employment and greenhouse gas (GHG) emissions. This study uses the CleanProdLT computable general equilibrium model based on the latest available data for 2020. The model allows for analysis of economy-wide effects by considering cleaner production and more sustainable consumption scenarios at different levels of detail. The results of the analysis show that while the analysed substitution of plastic bags with bioplastic (BioPlastic scenario) or paper bags (PaperBags scenario) has positive socioeconomic impacts, the overall best results can be achieved by reducing their consumption (ConsReduction scenario). In detail, it is estimated that the GDP could increase by EUR 18 million under the PaperBags scenario, by EUR 47 million under the BioPlastic scenario, and by EUR 64 million under the ConsReduction scenario. At the same time, employment increases by 213 jobs, 891 jobs, and 449 jobs, respectively. While the PaperBags and the BioPlastic scenarios reveal increases in GHG emissions of 4.5 $ktCO_{2eq.}$ and 29 $ktCO_{2eq.}$, respectively, the ConsReduction scenario demonstrates a decrease in GHG emissions of 4 $ktCO_{2eq.}$. These findings suggest that the recent policy decision to charge for plastic bags in supermarkets will have positive environmental and socioeconomic impacts in the future.

Keywords: carrier bag waste; socioeconomic impact; computable general equilibrium; cleaner production; sustainable consumption

Citation: Lekavičius, V.; Bobinaitė, V.; Balsiūnaitė, R.; Kliaugaitė, D.; Rimkūnaitė, K.; Vasauskaitė, J. Socioeconomic Impacts of Sustainability Practices in the Production and Use of Carrier Bags. *Sustainability* **2023**, *15*, 12060. https://doi.org/10.3390/su151512060

Academic Editors: Premakumara Jagath Dickella Gamaralalage, Thammarat Koottatep, Kavinda Gunasekara and Amila Abeynayaka

Received: 5 July 2023
Revised: 29 July 2023
Accepted: 3 August 2023
Published: 7 August 2023

1. Introduction

While the planet is facing climate change, biodiversity loss, and a pollution crisis, humanity continuously increases its consumption, primarily through traditional (conventional) manufacturing. The United Nations invited a transformation of the world by announcing the 2030 Agenda for Sustainable Development [1]. It requests the protection of the planet in several ways, including implementing sustainable consumption and production patterns (SDG12) [2]. The European Union (EU) is committed to the 2030 Agenda, and SDG12 is part of the European Green Deal—a new sustainable growth strategy [3]. Within it, cleaner production and circular economy are recognised as relevant sustainability concepts [4–6], the implementation of which provides significant benefits, including environmental protection, reductions in raw materials dependence, job creation, savings of consumer money [7], etc. At the company level, waste reduction and decreases in operating costs [8] also play an important role. Nowadays, they are applied in sectors using many resources and having the potential for cleanliness and circularity. Packaging and plastics are among them, and the carrier bags are a separate case.

Carrier bags, being light, inexpensive, and convenient, are excessively used (5 trillion a year [9,10]) in the daily lives of humanity to carry groceries and goods from shops to home. They are single-use or reusable [11], and they are made of plastic, paper, cotton, jute, hemp, or polypropylene [12]. Although plastic carrier bags are barely reusable, they are mainly used [13] and are among the most discarded items in the EU [14]. Although the EU Member States (MS) reported that during 2018–2020 they reduced consumption of plastic bags by 7.5% [15], consumption remained relatively high—in the EU, on average, 87 lightweight plastic carrier bags (LPCB) were used per person in 2020, although three times more were used in Lithuania (294 bags) [15], while the global average was around 700 [9]. In addition, their recycling rate is estimated to be low and reaches 1 to 6.6% [11]. Understanding the harmful impacts of plastic carrier bags across the economic, social, health, and ecological aspects of life [16], the EU insists on reducing LPCB consumption and searching for cleaner production practices. In detail, the Plastic Bags Directive [17] obliges countries to reduce plastic bag consumption by more than two-fold to 40 units per person by 2025 by taking various measures. The results of the scoping study [18] revealed that bans on free distribution, charges for plastic bags, prohibition of production and imports, and exemptions of biodegradable bags from environmental fees are applied for this purpose. Responding to EU-wide policy changes, from mid-2023, in Lithuania, the Law on the Management of Packaging and Packaging Waste [19] bans free-of-charge distribution of LPCB and very LPCB (below 15 microns), except for packaging fresh meat and fish and their products, and the market is assigned the role of searching for sustainable alternatives. The socioeconomic and environmental consequences of the implemented changes in legal provisions in the country remain unknown, although they are necessary in the context of Lithuania's progress strategy "Lithuania 2030" [20] and the related National Progress Plan 2021–2030 [21] inviting smart economy development. Moreover, the Plan [21] states that there is no information and data on progress in the SDG12 area, the issue covered by this paper, in the country. Therefore, research concerning sustainable production and consumption practices for plastic carrier bags is timely and valuable from a practical point of view.

Worldwide research provides evidence that economic and non-economic measures imposed in relation to plastic carrier bags quickly change customers' behaviour. Within one month of implementing the measures, the use of plastic carrier bags is significantly reduced [22]. Reductions are fixed among gender, different ages and income groups [23]. Moreover, the research measures the impact of the substitution of single-use plastic bags for multiple-use ones [24] or bags determined to be reusable, trolleys, and using no bag but carrying the products in hands [25]. If measures are further strengthened, the share of people who do not use any plastic bags increases, followed by more people choosing eco-friendly alternatives [24]. These behavioural changes are caused by environmental concerns instead of economic circumstances [24], which are found to be more relevant for opponents of such measures [25]. Understanding the damage caused by plastic bags, people are ready to pay for them. It is said that the willingness to pay (WTP) for LPCB is lower than for multiple-use plastic bags, and it is found to be higher and not matching the existing levy [24], calling for policy updates to eliminate the discrepancies. This could include a subsidy for expensive durable and reusable shopping bags or an increased levy on single-use plastic bags [26]. The measures facilitate the introduction of other policies for eliminating single-use plastics, waste and packaging [23].

Numerous scientific studies concerning the negative environmental impacts of plastic carrier bags have proven the damage they cause. Death of animals, non-biodegradability, use of petroleum products, having toxic chemicals and their release during manufacturing, blocking drainage systems, causing the Great Pacific Garbage Patch, risks of lung complications, reproduction issues and cancer in people, water pollution, oceans with plastic and other harmful effects are identified among the primary damage. [16]. In addition, litter in public open spaces is considered a major environmental and aesthetic problem [10]. Communities are aware of environmental problems related to the intensive use of plastic carrier bags, but still, sustainable alternatives are lacking [27]. To quantify the environmental impacts of carrier bags across different environmental impact categories, a life-cycle assessment (LCA) was carried out [28]. Its results revealed that polypropylene (PP) bags have the highest global warming potential (GWP), followed by biodegradable thermoplastic and low-density polyethylene (LDPE) bags [28]. The largest share of environmental impacts comes from the granulate production process, while the impact of transportation is negligible if the bag is manufactured domestically but relevant if it is produced abroad. When examining and comparing a larger variety of carrier bags over the environmental impact categories of depletion of abiotic resources, photo-oxidant formation, eutrophication, acidification, human toxicity, and aquatic and terrestrial toxicity, it is found that the cotton bag has a 10 times higher GWP than the PP bag [29]. The high-density polyethylene (HDPE) bag has the lowest GWP. It has the lowest environmental impact in eight of the nine impact categories. The GWP is dominated by raw material extraction and the manufacturing process. Seeking to reduce the environmental impacts of carrier bags, they should be reused as much as possible. Recycling ensures only a small reduction in the GWP [29]. Similarly, reusing is better than recycling after an analysis of 13 types of carrier bags in 15 environmental impact categories [30]. LDPE provides the lowest environmental impact. Heavier carrier bags, such as PP, PET, polyester, bleached paper and textile bags, must be reused several times to lower their environmental production cost. The latest Norwegian study [31] demonstrates that multi-use carrier bags should be preferable to single-use ones. Under the cut modelling approach, paper bags are estimated to have the highest potential for human health and resource damage, while under the net scrap modelling approach, plastic bags have the most significant potential in those categories. Moreover, if littering is an issue, then priority should be given to the bio-content alternatives (paper, cotton and cardboard). Seeking to support policy making, the environmental impacts of plastic bag bans (PBB) are assessed. It is found that PBB reduce single-use bags by 86% (348 million a year) but increase reusable bags use by 40% and lead to an increase in paper bags from 3 to 16% [32]. In addition, due to PBB and related fees, less energy is required, less solid waste is generated, and fewer GHGs are emitted, although more water is required. Recycling practices perform better than incineration and landfill [33].

While the environmental impacts of carrier bags are well addressed in the scientific literature, the socioeconomic impacts on policy making and its justification remain little investigated or unknown, especially at the country level and quantitatively instead of descriptively. Even though existing quantitative studies provide a variety of evidence, they are based on not clearly specified methods of assessment [32] and surveys [34,35]. The results of economic impact assessments of PBB and fees performed via not specified assessment methods reveal that local economies are not negatively affected in the long term because there is a shift from single-use to reusable bags [32]. Cities experience savings through litter abatement and no evidence is found of job losses [32]. The results of surveys demonstrate that PBB increase the price for consumers, decrease the profit for producers, and decrease economic activity in the area affected by the PBB [34]. Furthermore, PBB reduce employment in the shops under the PBB, although in the shops outside the PBB, employment increases [34]. Moreover, charging for plastic bags leads to a decrease in the use, production and sales of LPCB bags. However, the significant impacts on the economic sectors are avoided [35].

Given the limited literature on the socioeconomic impacts of carrier bags, the present study makes several contributions. Firstly, a socioeconomic impact assessment framework has been developed to analyse scenarios at different levels of detail. Secondly, the economy-wide analysis allows for a more accurate assessment of the impacts of environmentally friendly solutions on society beyond individual economic segments. Thirdly, the country analysed is characterised by its high production and consumption of plastic bags in the context of the EU, which makes the analysis useful for other countries, including developing economies. Finally, the socioeconomic impact assessment is largely based on the most recent publicly available data, with additional disaggregation, and focuses on key scenarios in the field of plastic bags, making it particularly relevant for policy making.

Responding to the policy objectives regarding sustainable production and consumption patterns based on cleaner production and circular economy practices, and continuing the ongoing research in this area, the paper focuses on the sustainable production and use of plastic carrier bags and their alternatives in Lithuania, and on the possible implications of recent updates to the Law on the Management of Packaging and Packaging Waste [19] regarding the rationality of accepted measures in terms of the socioeconomic impacts they cause.

Thus, the paper aims to assess the socioeconomic impacts of the production and consumption of plastic carrier bags and their sustainable alternatives in Lithuania.

Responding to that aim, the goal of the paper is four-fold: (1) to assess the socioeconomic impact of sustainable alternatives to plastic carrier bags based on changes in the country's GDP; (2) to estimate the impact of them on the establishment of supplementary job places; (3) to evaluate the environmental aspect of sustainable alternatives to plastic carrier bags; and (4) to carry out a comparative analysis of the proposed alternatives to plastic carrier bags.

From a practical point of view, the sustainable practices of carrier bags used and produced in Lithuania are assessed for the first time. The findings provide relevant inputs for policymakers when forming and implementing related policies. For this purpose, the CleanProdLT general equilibrium model was developed, which is a suitable tool for analysing a set of socioeconomic and environmental impacts of different strategies that could be applied to sustain cleaner production practices by considering the most relevant policy-making criteria, such as economic growth, employment and GHG emissions.

The rest of the paper is organised as follows. Section 2 introduces the research steps carried out, the methods applied, and the data used. Section 3 presents the scenarios of sustainable practices for plastic carrier bags. Section 4 is dedicated to presenting and discussing the research results. Finally, in Section 5, the conclusions are drawn.

2. Materials and Methods

The socioeconomic impact of sustainability practices in the production and use of carrier bags is analysed in this paper through a dedicated modelling framework in which the general economic equilibrium model CleanProd plays a central role. The model is based on the Social Accounting Matrix (SAM), which is developed using the latest available data for 2020.

2.1. Modelling System

The socioeconomic impact evaluation process in the specific case of carrier bags explored in this paper is illustrated in Figure 1, which also shows the main steps of the present research.

The general equilibrium model CleanProdLT is used as the primary tool for the socioeconomic impact evaluation presented in this paper. It is the Lithuanian version of the CleanProd model, a general equilibrium model designed especially for analysing the adoption of cleaner production practices and the transformation of industries. Therefore, the model reasonably realistically reflects both economic and physical linkages. The CleanProdLT combines input–output quantity and price models [36] but, unlike conventional input–output analysis, endogenises final consumption under representative agents' budget constraints. The general equilibrium in the model is achieved by combining the results of the price and quantity models with iterative computations to find the equilibrium in all the markets.

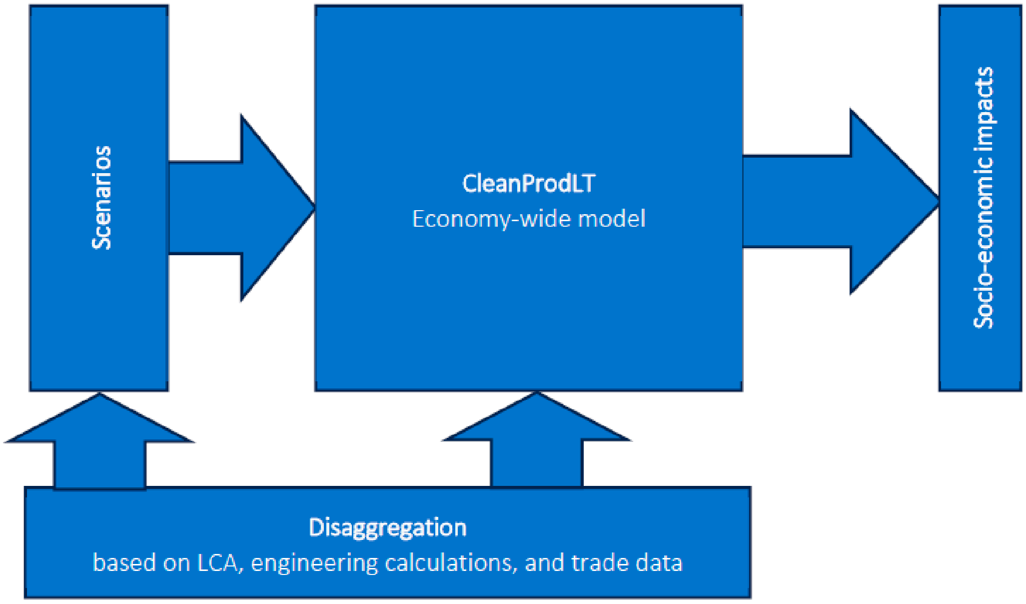


Figure 1. Socioeconomic impact assessment system (developed by the authors).

The structure and modelling flow of the CleanProd general equilibrium model are illustrated in Figure 2, which summarises the actual elements of the model implemented in Microsoft Excel 365.

The three blue blocks, the Original Social Accounting Matrix (Original SAM), the Matrix of Changes in the SAM Structure, and the Reference SAM, cover the preparatory modelling work. First, the Original SAM is compiled and balanced based on statistical data. The Matrix of Changes in the SAM Structure is designed to integrate the new products into the Original SAM. Thus, when a disaggregation of one or another product is carried out (see the full description of the data preparation below), all the changes (both new products and changes to existing products) must be entered into the SAM structure change matrix. The Reference SAM is the sum of the first two matrices. Since the changes in the structure of the SAM must be balanced, it is natural that the Reference SAM is also balanced. This matrix is ultimately used for socioeconomic assessments, providing indicators of the original economic equilibrium.

The three blocks in dark blue correspond to integrating the scenarios into the economy-wide computational model. From the perspective of the CleanProd model, the scenarios are integrated as changes in the structures in the Scenario Matrix. This is where the changes foreseen in the scenarios (increases or decreases in the intermediate consumption of different products, changes in factor inputs, changes in demand, etc.) are presented. As the cleaner production scenarios are usually only seen from the perspective of one or more economic activities, it is natural that the Scenario Matrix, unlike the Reference SAM, is not balanced (the sum of the rows does not equal the sum of the columns). It must be stressed that the Scenario Matrix does not present the new structures resulting from the transformation of the economy but rather the changes compared to the existing (reference) structure. Thus, adding the Scenario Matrix elements to the Reference SAM elements results in an unbalanced SAM with corrections.

In this case, the imbalance in the matrix is natural, as it reflects the nature of the scenarios and thus illustrates the logic of the expression of the socioeconomic impacts, according to which transformations of industries or changes in consumption at the initial stage can be seen as a disturbance of the general equilibrium of the economy, followed by changes leading to a new general equilibrium state.

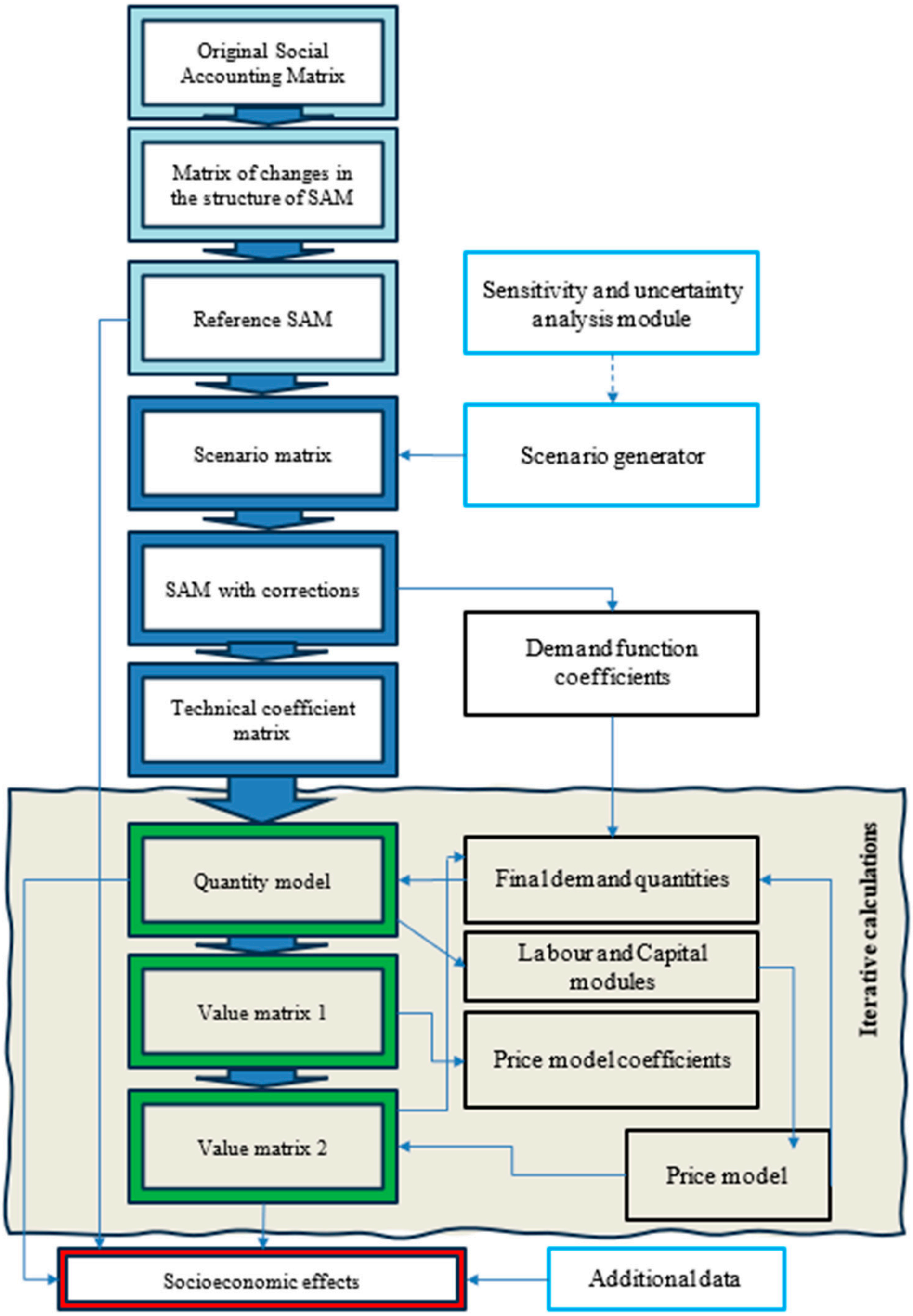


Figure 2. Structure and simulation flow of the CleanProd general equilibrium model (developed by the authors).

The SAM with corrections does not represent a market equilibrium but rather describes the structures of the industries to be achieved in the new equilibrium state. In other words, the SAM with corrections already suggests how the modelled industries operate and produce products. However, it is not yet clear how the market forces will lead to the economic equilibrium and what output will be achieved. As a result, the unbalanced SAM with corrections is used to calculate the technical coefficients for the quantity model, to determine the parameters of the demand function, and to determine the technical coefficients for the transfer matrix. The technical coefficients are determined by dividing the elements of the matrix in the columns by the sums of the columns, i.e., they reflect the share of each element in a column of the matrix:

$$a_{i,j} = \frac{x_{i,j}}{\sum_i x_{i,j}}, \tag{1}$$

where $a_{i,j}$ is a technical coefficient, $x_{i,j}$ is an element in the unbalanced matrix with corrections, i is the SAM row index, and j is the SAM column index.

While the steps discussed above represent the preparatory part of the general equilibrium simulation with the CleanProd model, the rest are dedicated to finding the new equilibrium state. Here, price and quantity models for input–output analysis [36] play a key role.

A quantity model can be defined as follows:

$$A \times x + y = x, \tag{2}$$

where A is a matrix of physical technical coefficients, x—is a vector of output quantities, and y is a vector of final consumption quantities. In other words, for each product group, x must be produced/imported in such a quantity that it is sufficient to satisfy both the final consumption (vector y) and intermediate consumption ($A \times x$).

Rearranging the equation gives:

$$x = (I - A)^{-1} \times y, \tag{3}$$

where I is the unitary matrix.

Thus, the output quantities for each product can be calculated by knowing the quantities of the final consumption and using Equation (2). Multiplying the output quantities by the technical coefficients, in turn, gives the intermediate consumption for each element of the social accounting matrix:

$$x_{i,j} = a_{i,j} \times \sum_i x_{i,j}. \tag{4}$$

An analogous principle is used to calculate the quantities of imports used in the intermediate consumption, assuming that the imports in the SAM are an input component of production in the country considered.

When a transformation occurs in a branch or branches of the economy, the quantity model is used to calculate the new quantities of products produced and consumed in the economy. Using the commodity prices, monetary values can be calculated to obtain a new SAM. As a rule, only part of this matrix will be balanced, since changes in the production structure also change the production factor incomes and, consequently, the consumption possibilities of the agents representing the economic sectors.

Whereas in a conventional input–output analysis, the final consumption is determined exogenously, in a general equilibrium model, the quantities of the final consumption demand are determined by the budgets of representative agents (institutional sectors), which are deducted from the SAM. In the CleanProd model, it is possible to change the demand functions easily, although the demand function derived from a Cobb–Douglas-type utility function was used in this paper.

The budget constraint is derived from the Value Matrix 2 discussed below and the product prices from a price model that estimates the final product prices, taking into account, among other things, changes in the prices of the intermediate consumption products.

The price model is constructed based on similar principles to the quantity model, and the product price vector is calculated according to the equation:

$$p = \left(I - A^T\right)^{-1} \times w^T, \tag{5}$$

where I is the unit matrix, p is the product price vector, $\left(I - A^T\right)^{-1}$ is the transposed inverse Leontief matrix, and w^T is the transposed vector of the primary resources, as determined by the change in the price of labour, capital and, in the case at hand, of the imported products for intermediate consumption. To calibrate the price model (to calculate the technical coefficients), Value Matrix 1 is used, which uses the prices that existed before the changes in the primary resource prices.

As the model focuses on analysing the socioeconomic impact of industrial transformations, the labour market is reflected in the model by anticipating the possibility of varying levels of unemployment depending on the real wage changes. To this end, a wage curve approach [37,38] is integrated into the model following the modelling methodology developed by Küster et al. [39].

Obviously, a change in the value of one variable in the model affects the values of the other variables. For example, a new value of the budget constraint leads to a change in the final demand, resulting in changes in the output and consumption of intermediate products and, hence, in the demand for the primary factors of production. Some of the aspects discussed are calculated automatically, so that, for example, the quantity model always reaches equilibrium, while others require iterative calculations (which are also related to the specificities of the practical implementation of the model). In the CleanProd model structure, iterative calculations are used to (a) balance the labour market; and (b) balance the demand and the budgets of representative agents.

Value Matrix 2 is fully aligned with the quantity model and uses the prices calculated by the price model. In addition, the values of transfers between institutional sectors are deducted in the Value Matrix. After the transformation, the Value Matrix 2 is unbalanced, although the iterative calculations, where the budgets of the representative agents and the new prices of the products generate new quantities of demand, bring the Value Matrix 2 into balance. The iterative calculations, once equilibrium has been reached, produce a new SAM reflecting the new general equilibrium situation, which, together with the quantity model and the Reference SAM, are used to assess the socioeconomic impacts of cleaner production.

In methodological terms, three types of indicators can be distinguished: (1) standard socioeconomic outputs from the computable general equilibrium model (CGE model); (2) baseline indicators derived from the CGE model and used to calculate secondary indicators; and (3) secondary indicators calculated using the baseline indicators. The calculation of the secondary indicators is carried out using principles analogous to a social life-cycle analysis (LCA). For example, the primary indicator derived from general equilibrium modelling is the amount of labour involved in economic activity. Labour intensity indicators can then be used to calculate the number of employees in the activity in question as a secondary indicator, as it is not captured within the model itself. Moreover, the number of employees in the activity can be disaggregated according to certain characteristics of the employees in the base year of the modelling or in the forecast year, such as gender, age, skill level or similar. This methodological framework makes it possible to analyse socioeconomic indicators and other indicators related to sustainable development. For example, GHG emissions in industries with no change in production processes (no change in emissions intensity) are calculated by relating the GHG emissions to the output quantities. Multiplying the GHG emissions intensity indices by the output of the industries gives the emissions in the new equilibrium state.

The sensitivity and uncertainty analysis capabilities built into the CleanProd model can be used both for its traditional purpose of assessing the uncertainties in the modelling results and the factors influencing them, and for a deeper understanding of the factors influencing the modelling results. A systematic sensitivity and uncertainty analysis is carried out, for which a Monte Carlo approach is used to generate sets of at least 100 cases and to assess the impact of the factors on the uncertainty of the modelling results, which are, in turn, assessed using the dispersion of the results across the cases, based on the correlations of the factors considered with the socioeconomic indicators under consideration. For the sensitivity and uncertainty analysis, the CleanProd model provides two alternatives: using internal tools or external software packages. In both cases, the sensitivity and uncertainty analysis module of the CleanProd model is used to feed the values of the sensitivity and uncertainty analysis factors into the scenario generator and to automate the general equilibrium modelling under changing factor values.

2.2. Data Sources and Disaggregation Procedures

The basic version of the model covers 63 products of economic activities that correspond to the Nomenclature of Economic Activities in the European Community (NACE) and the Classification of Products by Activity (CPA). The commodities are depicted at the level of CPA 2 digits based on data availability. According to the idea of assessing the socioeconomic impact of cleaner production processes and other industrial transformations, the analysis is bottom-up based, i.e., a detailed analysis of cleaner production practices (process-based LCA or techno-economic calculations) leads to more aggregated production scenarios, thus maintaining the possibility of assessing the impacts of even relatively small changes in production processes. This principle requires an appropriate choice of data sources, focusing on the detailed reflection of processes rather than aggregated information on entire industries, which primarily reflects the economic structure of one country or another. To enable the analysis of production practice changes in the CGE modelling framework, additional possibilities are foreseen to analyse specific products in more detail in the CleanProd model. The model can accommodate additional economic activities obtained by disaggregating existing economic activities so that the relevant production areas can be analysed in the context of their relationships with the rest of the economy and by considering the inter-industry linkages.

The main data sources used to create the SAMs for the CleanProd models are the FIGARO database for 2020 [40–42] and Eurostat's non-financial transaction statistics for the same year [43]. For many countries, the FIGARO and non-financial transaction statistics are not fully compatible (the non-financial transaction statistics are updated more frequently than the FIGARO data published in 2022), so the resulting initial SAM, which is based on the raw statistical data, is balanced by minimising the deviations from the original values, thus ensuring consistency between all the elements of the matrix to obtain the Original SAM depicted in Figure 2.

As mentioned above, the CleanProdLT represents a generic model (a universal modelling framework that is adaptable to the particular analysis), so the first stage of the study is to adapt it to the scientific research questions; in this case, the socioeconomic impact of the production and consumption alternatives to plastic carrier bags. In the statistics and in the FIGARO dataset, carrier bags are reflected as part of the CPA category CPA_C22 Rubber and plastic products. Still, more products, such as rubber tyres for cars or builders' ware of plastic (floor coverings, plastic windows, etc.), fall under this category. It is clear that although they are classified in the same CPA category (which suggests a certain similarity) in the Reference SAM, these products have different cost structures and uses. Consequently, it is necessary to disaggregate the CPA_C22 category of Rubber and plastic products in the SAM, separating bags made of ethylene polymers into a separate category. This is done, in particular, by means of LCA studies, which make it possible to identify the essential material and energy elements used in the production of bags.

The life-cycle inventory analysis can be considered an initial source of information on the production processes under consideration. Still, additional actions need to be taken in order to prepare data suitable for economic modelling. Although the LCA procedures are standardised, and while many freely available and paid databases for LCA provide detailed information on processes and products, previously performed case studies have shown that the quality and relevance for the particular case of these information sources vary widely and need to be verified with additional information. For example, life-cycle databases provide several process alternatives for producing conventional plastic bags, and different system boundaries can be selected. However, other sources (in this case, PRODCOM data on Sold production, exports and imports (dataset DS-056120) [44]) indicate that primary polyethylene is almost not produced in Lithuania. Thus, it shall be described as an import. This paper also analyses a new production practice involving substituting conventional plastics with bioplastics as one of the scenarios. Therefore, both the modelling of conventional plastic bags and the modelling of bioplastic bags are based on the same information sources for consistency [45].

As the main purpose of LCA is environmental impact assessment, the LCA databases usually focus on physical rather than economic indicators. Even if economic data are provided, they may need to be updated due to the relatively slow updating of databases or inconsistency with the rest of the modelling database due to different methodologies. In this respect, both the disaggregation of the SAM and the development of scenarios based on physical flows are converted into monetary units for the period modelled. The datasets in the Comext database [44] are also used as a data source. Their order of priority to be used in the modelling is as follows: (1) dataset on Sold production, exports and imports (DS-056120, this dataset is preferred owing to the fact that it allows the determination of the domestic production price and the estimation of the domestic production of specific commodities); (2) EU trade since 2002 by CPA 2.1 (DS-059268, although this dataset only provides import prices to be used as a proxy, as its commodity classification is consistent with that used in the social accounting matrix); and (3) EU trade since 1988 by HS2-4-6 and CN8 (DS-045409). Finally, if none of the datasets provide price data for data transformation into monetary units, the authors' own data collected from various other sources are used. A good case in point is energy prices. While the mentioned datasets fail to provide relevant information on domestic energy prices for businesses, they can be easily obtained from Eurostat's databases.

Even fewer data exist for the disaggregation of the commodity consumption in the SAM. Still, the dataset on Sold production, exports and imports (DS-056120) provides detailed information on the aggregate flows, which is useful to support the disaggregation of the intermediate and final consumption. The main methodological limitation of the paper is that the tables that make up the SAM are prepared using a top-down approach and, therefore, do not sufficiently reflect the specificities of the individual components. In this paper, only the production of bags made of ethylene polymers was analysed in detail, not the other products making up CPA_C22. Consequently, the methodological principles used differ, and the subtraction of the cost structure elements for plastic bags does not necessarily lead to a suitable structure for the remaining products. On the other hand, the use of the structure in the SAM also has implications for the disaggregation, as it defines the totals, which may significantly affect the attempts to disaggregate the products that are predominantly in one or another CPA category (some intermediate consumption amounts that used the product under consideration may not fit the existing cost structure). However, this limitation also applies to supply–use and input–output (I–O) tables in general, and the benefits of reflecting a realistic economic context in the socioeconomic impact analysis outweigh the limitations discussed.

Disaggregation of the commodity CPA_C22 Rubber and plastic products results in a new balanced SAM with an additional commodity (Reference SAM shown in Figure 2). The values of the CPA_C22 heading were calculated as the difference between the original values of the Reference SAM and the newly disaggregated Sacks and bags made of ethylene polymers, which allows for maintaining the balanced matrix. Thus, CPA_C22 now reflects Rubber and plastic products, except for Sacks and bags made of ethylene polymers. In order to ensure the replicability of the study, the constructed Reference SAM with disaggregated Sacks and bags made of ethylene polymers is openly available [45]. The disaggregated SAM is published in csv (comma-separated values) format, allowing easy transformations to suit modelling needs. This disaggregated SAM is further used as the basis for the socioeconomic impact assessment of the scenarios considered.

3. Scenarios of Sustainable Practices

In order to make the scenarios realistic, they are linked to an analysis of existing statistics on the use of plastic bags in EU countries. Figure 3 shows the per capita quantities of polyethylene plastic bags (22221100 Sacks and bags made of ethylene polymers (including cones) according to the PRODCOM classification) in EU countries.

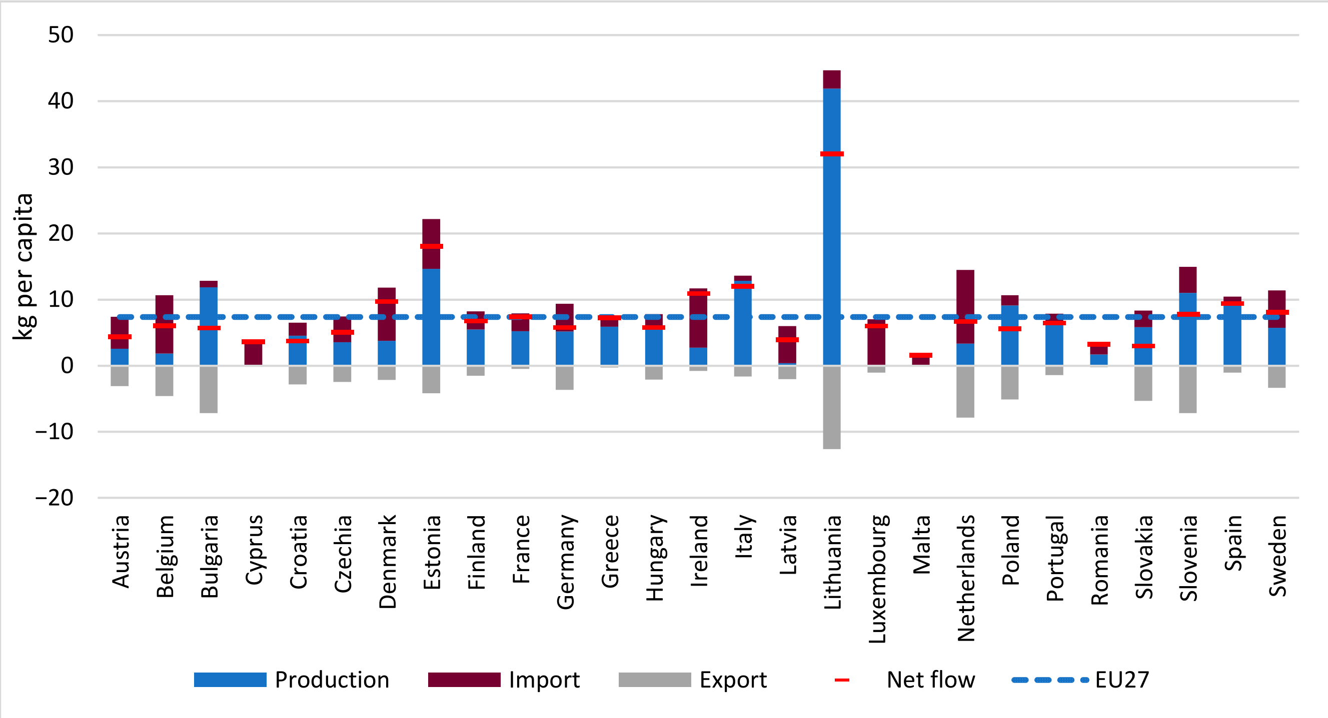
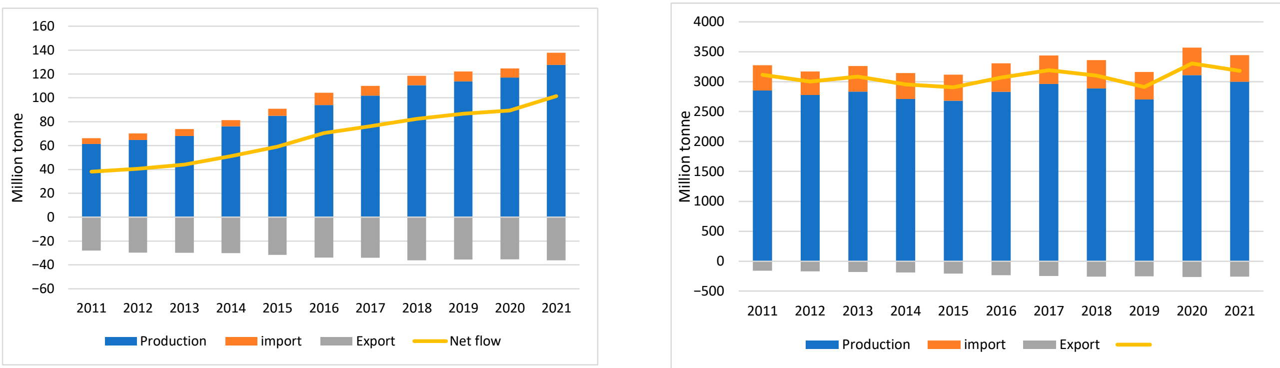


Figure 3. Production and international trade of bags and sacks made of ethylene polymers in EU countries in 2020 (developed by the authors based on Eurostat data [44]).

The net flow shown in Figure 3 does not necessarily correspond exactly to the consumption of bags in the country, as it may also be related to, for instance, a change in stocks. Nevertheless, Figure 3 illustrates the overall trends quite well and justifies this paper's motivation to focus on the Lithuanian case study. As Figure 3 shows, Lithuania's total ethylene polymer sacks and bags per capita in 2020 was around 32 kg, 4.33 times higher than the EU average. This offers some indication of the potential scale of the reduction, which is further strengthened by the dynamics shown in Figure 4.

Figure 4 shows fairly divergent trends in Lithuania and the EU as a whole. While in the EU, import and production volumes have been relatively stable (4–5% growth over the 2011–2021 time frame) and exports have increased by 62% (from 160 million tonnes (Mt) in 2011 to 220 Mt in 2021), in Lithuania, the changes have been more pronounced. Here, exports grew by 30%, and production and import volumes more than doubled (it should be noted that imports account for a small share of the total sacks and bags, so the small base has impacted the growth rate). Given the environmental impact of plastics, these trends show a clear need for action.

As the literature analysis has shown, reducing plastic bag pollution requires complex measures covering both production and consumption. Practical considerations also suggest that narrow solutions may not be sufficient due to the specificities of applying environmentally friendly solutions. However, for the purpose of socioeconomic impact analysis, a domain-specific scenario design is appropriate, as it allows the identification of priority policy areas. The scenarios analysed in this study cover both the supply and the demand side, thus encompassing a shift towards sustainability in production by introducing cleaner production practices and a behavioural change towards more sustainable consumption. Although not always intuitively perceived, the attribution of structural changes to the demand or supply side is relative, and the case of plastic bags illustrates this very well. Although the reduction in plastic bag consumption is primarily attributed to end users, a large proportion of plastic bags are used in trade and the food industry and are delivered to consumers with the goods they buy. Thus, these bags are reflected in the SAM as elements of the intermediate consumption in the relevant economic activities. In this case, the reduction in bag volumes implies an increase in the efficiency of economic activities, which also requires a change in consumer behaviour. A list of the scenarios analysed with the key assumptions is presented in Table 1.



(**a**) (**b**)

Figure 4. Production and international trade in sacks and bags made of ethylene polymers in 2011–2021: (**a**) Lithuania; and (**b**) EU (developed by the authors based on Eurostat data [44]).

Table 1. Scenarios analysed (developed by the authors).

Short Name	Description
PaperBags	3/4 of the current uses of plastic bags in retail, wholesale and households are replaced by paper bags; 1/2 of plastic bags in the food industry are replaced by paper bags.
BioPlastic	3/4 of the current uses of plastic bags in retail, wholesale, food and households are replaced by bioplastic bags.
ConsReduction	The use of plastic sacks and bags is reduced by 3/4 in retail, wholesale, and households and by 1/2 in the food industry.

The analysis of recent trends in the production and use of plastic bags in Lithuania allows the definition of the set of scenarios listed in Table 1.

As the base year of the CleanProd model is 2020, the scenarios are also based on this year's levels. All the scenarios focus on those areas of the supply chain where the use of polyethylene sacks and bags is the highest and take into account the specificities of economic activities. For instance, in the PaperBags and ConsReduction scenarios, the reduction in plastic bag use in the food industry is less pronounced than in the other areas, as the elimination of plastic bags or substitution with paper bags is often not possible due to food safety reasons. The changes analysed in the scenarios may seem ambitious, although their realism is confirmed by benchmarking with other countries. On the other hand, the alternatives considered represent different paths towards the same goal of reducing plastic use and waste. If, for whatever reason, a significant reduction in the use of plastic bags proves to be impossible, other means could be used to achieve the reduction objectives.

Integrating the scenarios into the model reflects the consumption reductions directly in the SAM by incorporating the structural changes in the economy. It is assumed that the reduction in sacks and bags consumption in economic activities is associated with additional advertisement campaigns, so that 20% of the value of sacks and bags is assumed to be attributed to the information campaign that accompanies this change, while the remaining value corresponds to a more cost-effective production process. The shift to paper bags in the model is represented by the increased consumption of paper products. As the production of bioplastic bags is a relatively new process, it is reflected in the model by creating an additional commodity, similar to the disaggregation of plastic sacks and bags made from rubber and plastic products based on LCA studies [46].

4. Results and Discussion

The socioeconomic impact of the scenarios considered is measured as the difference between the equilibrium state in the reference case and the new equilibrium state resulting from implementing the changes considered in the scenarios. Consequently, the results are generated through multiple socioeconomic impact channels and include different impacts, which are often divided into direct, indirect and induced effects [47].

Figure 5 shows the impact on the GDP of the scenarios considered. As can be seen from Figure 4, all the scenarios have a positive impact, although the magnitude varies. The ConsReduction scenario would have the most significant positive impact, increasing the GDP by EUR 64 million, while the BioPlastic scenario would have a positive impact on the GDP of EUR 47 million and the PaperBags scenario would have an impact of EUR 18 million. These changes represent up to 0.129% of the GDP, although the transformations under consideration are not major in the overall context of the national economy. In line with Luís et al. (2022) [35], modest changes in economic activity are fixed due to the replacement of plastic bags with their alternatives and their reduced consumption.

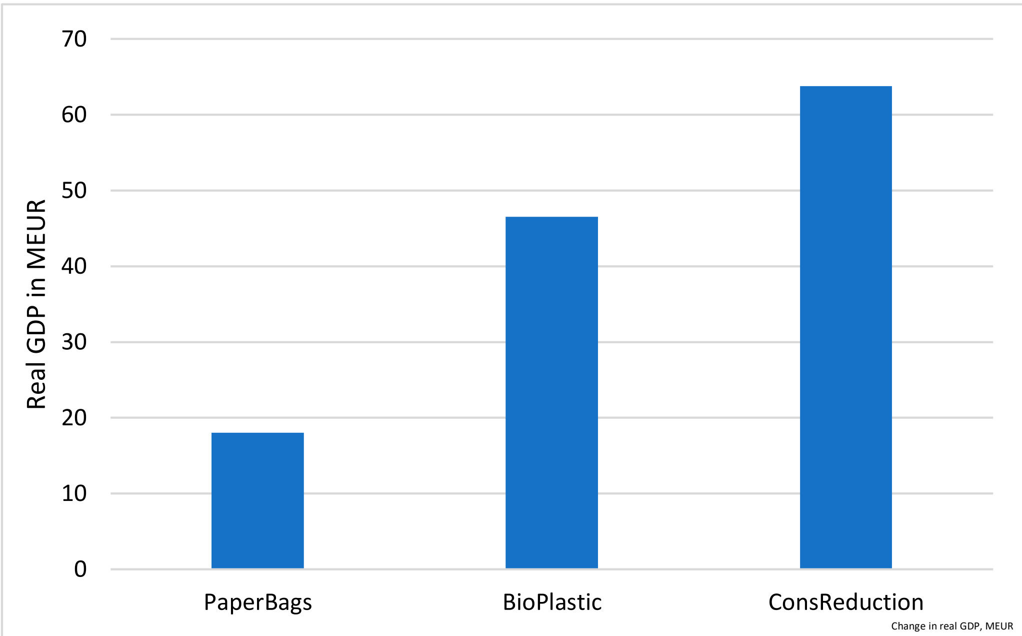


Figure 5. GDP impacts of the scenarios analysed (developed by the authors based on the modelling results).

The ConsReduction scenario with the largest impact on the GDP includes primary transformations in the food industry, wholesale and retail trade, and household consumption. The nature of these transformations is different. While in the case of households, a reduction in the consumption of sacks and bags leads to a redistribution and a change in the consumption of other products under the conditions of the household demand function, an increase in the efficiency of economic activities is observed in the other cases. For this reason, additional scenarios were tested to identify the main sources of the impact on the GDP. The reduction in the household consumption of plastic sacks and bags is found to have a positive but limited impact on economic growth (impact on the real GDP of EUR 8 million). In contrast, changes in economic sectors are responsible for most of the total effect. This can be explained by the fact that, according to statistical data, household consumption of bags is not significant (according to the untransformed FIGARO data [40], in 2020, the consumption of all the CPA_C22 Rubber and plastic products by Lithuanian households was only EUR 21.56 million. However, this amount includes other products in the category).

The limited impact of changes in households' final consumption is also determined by the mechanism itself, as the reduction in bag consumption leads to an increase in the consumption of other products. However, this does not always lead to more value added throughout the supply chain. A recent study on reducing food waste in different segments of the supply chain provides an analogy to these considerations [48].

On the other hand, reducing the use of plastic bags in economic activities is well-placed to impact GDP growth directly. In the context of the general trend towards greening, actions such as the elimination of free bags in shops are perceived as an element of social responsibility, although, in reality, they also contribute to the optimisation of the cost structure and potentially to the increase in corporate profits. Looking at the changes in value added by economic activities, the biggest winners are the directly affected food and trade activities, followed by construction, the directly affected advertising and market research activities, real estate activities and even public administration activities. Meanwhile, despite the overall growth, the value added falls most sharply in plastic bag production, textiles, transport and storage, and chemicals. Thus, at the level of economic activity, there are direct, indirect and induced effects.

The results of the employment impacts are presented in Figure 6. In contrast to the GDP, the BioPlastic scenario shows the best results, with an employment gain of 892 jobs or 0.065% compared to the reference scenario. In this scenario, direct changes in employment play a minor role, as the labour demand in the production of traditional plastic sacks and bags is replaced by the labour demand in the production of bioplastics, with a net effect close to zero. Employment changes are fairly evenly distributed across economic activities, with more pronounced gains in agriculture and construction. For the former, this is primarily due to the increased demand for raw materials for bioplastics production and labour intensity in agriculture (in terms of labour intensity, agriculture is second only to the activities of the membership organisation), while for the latter, it is due to the overall economic growth and the high share of construction in the fixed capital formation (the CleanProd model maintains the equality between saving and investment, so that as saving increases, investment increases as well).

The employment impacts of the other scenarios examined are more modest. The PaperBags scenario generates 213 jobs, mainly in the manufacture of paper and paper products, while the ConsReduction scenario generates 449 jobs spread across all the economic activities. There needs to be more known about the employment impacts of carrier bags. Therefore, a comprehensive discussion of the results is difficult. Our findings partially support the claim of the State Chamber of Oklahoma [34], who observed that due to PBB, employment decreases in one area but increases in others. They complement the results by providing net additional jobs due to the substitution of plastic bags with bioplastic and paper bags. The results also confirm that, due to substitution, significant employment impacts were not achieved [35]. However, in the short term, employment can reduce when plastic bag production facilities are closed [49].

Figure 7 shows the impact of the scenarios on GHG emissions from economic activities. It should be noted that these results do not include household emissions, as it would be challenging to infer changes in household emissions from changes in the total consumption. In the case of Lithuania, however, GHG emissions from households account for around 17% of the total emissions from economic activities and households. Changes in emissions from economic activities depend mainly on the intensity of the emissions from the economic activities under consideration and changes in the output of these activities, as the modelling assumes that technology changes only in the economic activities modelled in detail, the transformation of which is considered.

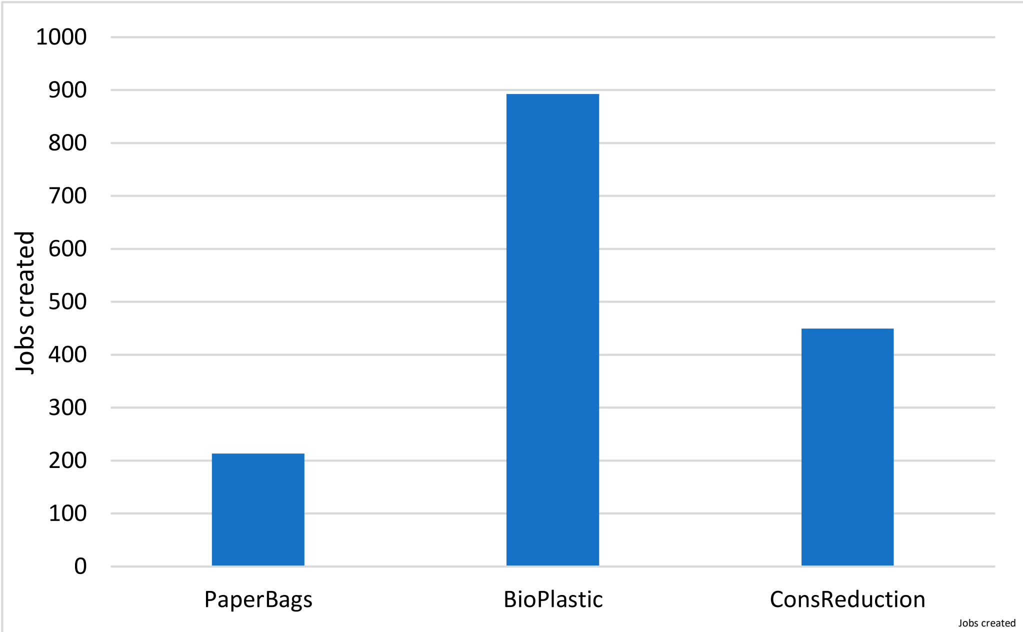


Figure 6. Employment impacts of the scenarios analysed (developed by the authors based on the modelling results).

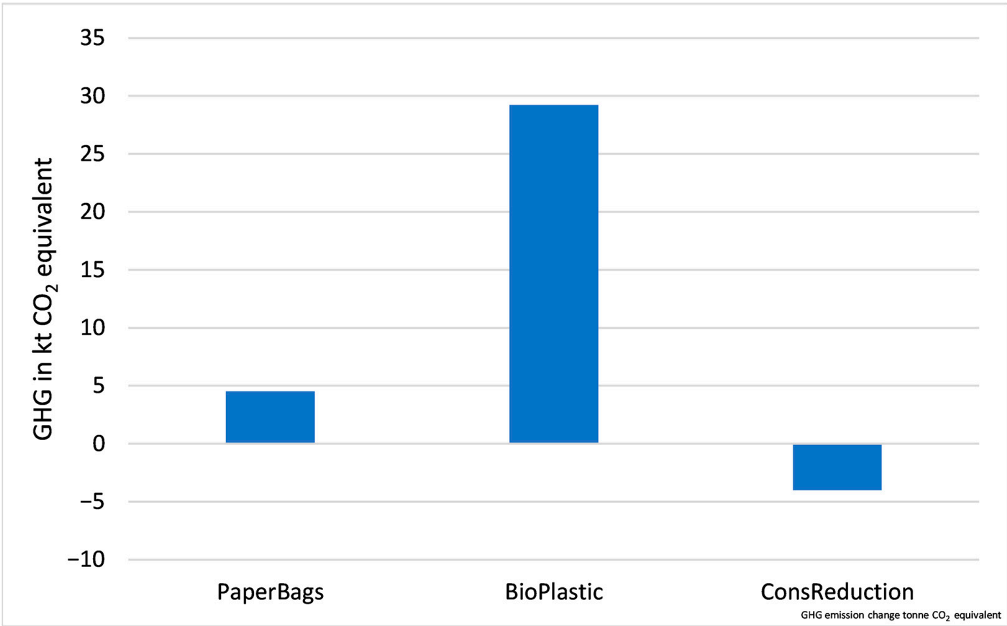


Figure 7. Impacts on GHG emissions in economic activities of the scenarios analysed (done by Authors based on modelling results).

As can be seen from the Figure 6, a reduction in emissions is only observed in the ConsReduction scenario, where the level of GHG emissions is reduced by 4000 tonnes of CO_2 equivalent (kt$CO_{2eq.}$) or 0.0179%, which is an order of magnitude smaller than even the GDP or employment. In this scenario, the emissions decrease most in land transport, chemicals, agriculture and plastics, and they increase in energy and construction. In the PaperBags scenario, the GHG emissions increase by 4.5 kt$CO_{2eq.}$, mainly due to an increase in emissions from paper production and land transport. The BioPlastic scenario demonstrates an increase in GHG emissions of 29 kt$CO_{2eq.}$, which is not due to direct emissions from the production of bioplastic bags but rather emissions related to the intermediate consumption products. According to Benavides et al. (2020) [46], the production of bioplastics requires significantly more energy inputs than conventional plastics. In the case of Lithuania, raw plastic is imported, so even the lower energy consumption for the domestic production of fossil plastic is not incurred. In contrast, in the BioPlastic scenario, moving a more significant part of the supply chain to Lithuania results in a reverse carbon leakage process, where the relocation of production increases both the domestic value added and the GHG emissions. In this scenario, the growth in GHG emissions is the strongest in energy, agriculture and chemicals. However, the growth in GHG emissions is not certain for agriculture and may be linked to methodological decisions. Although the use of agricultural products in the production of bioplastics is primarily linked to specific raw materials for starch production, agricultural products have yet to be disaggregated in the model, and the average emissions per unit of the agricultural output are used in the calculations. With these findings, this paper contributes to the stream of literature [10,16,28,30,50] dealing with the environmental impacts of plastic carrier bags and their alternatives by particularly focusing on changes in GHG emissions instead of GWP, depletion of resources, eutrophication, etc. [29], ozone depletion, cancer, etc. [30], or human health [31]. Specifically, they confirm that, independently, the material used to produce the carrier bags [12] causes environmental issues. However, these findings should be assessed with caution, as they depend on the environmental impact category and priorities. In line with Bisinella et al. (2018) [30], our paper found that plastic carrier bags have lower environmental impacts in comparison to their alternatives; therefore, they should not be completely abandoned in favour of paper and bioplastic bags, which increase GHG emissions. Ayalon et al. (2009) [10] argued that the prohibition of plastic carrier bags and their substitution with alternative options could lead to a non-rational environmental policy. Moreover, this is in agreement with the results of broader research [51] estimating that plastic solutions provide lower GHG emissions in 13 of the 14 applications where plastic was compared to alternative materials. In detail, it was assessed that the GHG emissions from the plastic solution are 10–90% lower than the next-best alternative [51]. A sustainable way to achieve savings in GHG emissions is to deliberately reduce the consumption of plastic carrier bags, as the results of the ConsReduction scenario demonstrated. This finding is supported by Bauer et al. (2022) [52], who proposed three pathways to reduce the GHG emissions from plastic, including reducing its consumption. Regarding the substitution of plastics with alternatives, it was argued that plastics should be replaced by materials associated with lower emissions [52]. The Lithuanian case demonstrated that, thus far, bioplastics and paper are inferior alternatives as they increase the economy-wide GHG emissions. This is in agreement with the finding of Ekvall et al. (2020) [50], who estimated that biodegradable bags are worse alternatives when it comes to climate impacts, acidification, eutrophication, and toxic emissions.

Comparing the GHG emissions and GDP growth of the scenarios as required by the Environmental Kuznets Curve (EKC) theory [53], it is noticeable that the ConsReduction scenario unties the GHG emissions from the GDP growth in the country. In detail, its results reveal that economic improvement could be achieved with reductions in GHG emissions. In contrast, the PaperBags and the BioPlastic scenarios link the GHG emissions and the GDP growth. Specifically, their results demonstrate that GDP growth is associated with the increases in GHG emissions, which are questioned by policy in the country.

As the results of the analysed scenarios are mixed, and as none of them shows the best results in all three areas discussed, the scenarios are compared by creating an integrated sustainability indicator that includes normalised values of the economic (GDP), social (employment) and environmental (GHG emissions) impacts. The values are integrated by assuming equal weights for each impact category, so that the highest possible value of an integrated indicator would be one and the lowest would be zero. It should be noted that the impact estimates have been normalised based on the results of the scenarios considered (min–max normalisation) and are only intended for comparison between them. The resulting indicator, therefore, reflects the impact of a scenario in the context of the rest of the scenarios. Still, it should not be used to interpret the impact of the whole set of scenarios. The values of this integrated sustainability indicator are shown in Figure 8.

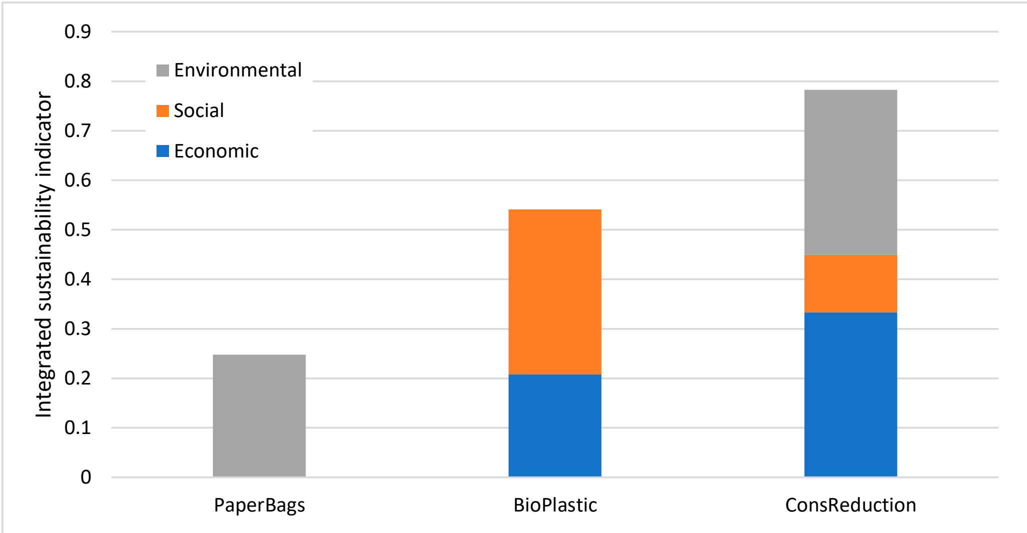


Figure 8. Scenario comparison by integrated sustainability indicator (developed by the authors based on the modelling results).

As shown in Figure 8, the ConsReduction scenario has the highest integrated indicator (0.78), comprising the components of all three areas. The BioPlastic scenario performs the worst on GHG emissions but shows the best employment performance. Its integrated indicator (0.54) is noticeably lower than of the ConsReduction scenario. The PaperBags scenario has the lowest integrated indicator (0.25) and demonstrates the worst socioeconomic impact performance among the scenarios considered, even though the increase in GHG emissions is less pronounced than in the BioPlastic scenario.

These results are confirmed by the uncertainty analysis of the integrated sustainability indicator, which looked at the influence of the weights given to the impact areas. Depending on policy priorities, different areas may be preferred, which makes such an analysis very important in practical terms. Random values were generated for all three factors, with new weights calculated for each set (resulting in weights following a normal distribution). After applying these weights, the values of the integrated indicator were recalculated for the scenarios, and the distributions of their uncertainties depending on the weights were obtained. The results of the calculations are presented in Figure 9.

Even after taking into account the sensitivity of the integrated sustainability indicator to the weights used to calculate it, the ConsReduction scenario shows the best results. For the absolute majority of the weight combinations, this scenario would outperform the PaperBags and BioPlastic scenarios. In 81 out of the 100 simulated cases, this scenario has the highest integrated sustainability indicator and is only below the BioPlastic scenario if a high weight is given to the new jobs created and the reduction in GHG emissions is ignored at the same time. In contrast, the PaperBags scenario underperforms in all the cases but outperforms the BioPlastic scenario if the highest weight is given to emissions. However, even then, the ConsReduction scenario is preferable, as it not only reduces plastic pollution but also emissions. Referring to that, our findings support the idea of "constructive quitting", which is perceived as a new growth strategy [54] to build something better [55]. The results of the survey, which revealed that customers support business and legislation reducing the unlimited accessibility to plastic carrier bags with a fee or ban [56], can have an impact on putting the idea into practice. The choice of a specific scenario to focus on in policy making also depends on the national priorities, although it is likely that the current strategy of the Lithuanian government to reduce the use of plastic bags will have an overall positive socioeconomic impact.

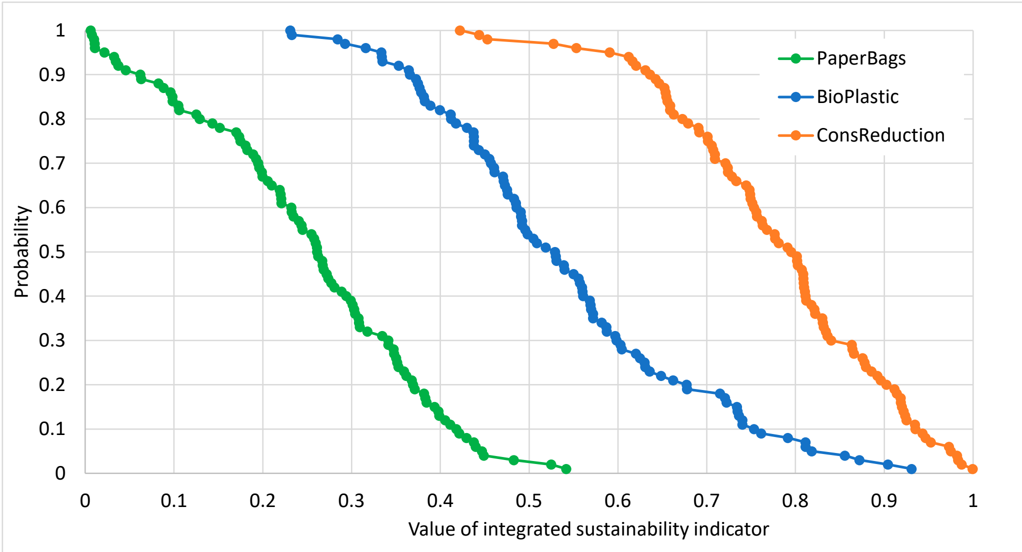


Figure 9. Uncertainties of integrated sustainability indicator for each scenario analysed (developed by the authors based on the modelling results).

The present study has limitations, which should be considered in future research. In particular, the scenarios analysed cover key sustainability practices in producing and using carrier bags. However, the scenarios' definitions are based on assumptions about the possible scale of the change derived from the EU benchmarking exercise. Additional empirical research would allow better identification of, for example, which part of the plastic bags used by the food industry can be eliminated and which part can be replaced with paper or bioplastic bags. Another limitation of the study relates to the level of aggregation of the industries concerned and assumptions about their homogeneity. As mentioned in the discussion of the GHG emission changes in the scenarios, economic activities are not homogeneous, so it is essential to analyse how the transformation of one economic activity affects the output of other economic activities and how the structure of these economic activities changes. This may require disaggregation not only of the production of carrier bags but also of the related industries. This aspect also highlights the quality issues of statistical data on inter-industry linkages. Although significant progress has been made in recent years, the industry's ongoing transformation requires more detailed data for evidence-based decision-making.

5. Conclusions

This paper analysed the socioeconomic impacts of the production and consumption alternatives to plastic carrier bags, including paper bags (PaperBags scenario), bioplastic bags (BioPlastic scenario), and the reduced consumption of plastic bags (ConsReduction scenario) in Lithuania by applying the CleanProdLT general equilibrium model, and the significance of the findings was strengthened by examining the environmental aspect too.

The results of the socioeconomic impact analysis of the changes in the GDP revealed that the country's economy benefits from the substitution of plastic carrier bags with paper bags, bioplastic bags and the reduced consumption of plastic bags at the estimated increases in the value of EUR 18 million, EUR 47 million, and EUR 64 million, respectively. This suggests that policies and measures oriented towards the limitation of and reduction in the consumption and production of plastic carrier bags could result in the most remarkable improvements in the GDP, which is minor compared to the national-wide GDP (0.129%).

The results of the socioeconomic impact analysis of the changes in employment demonstrated additional jobs subject to replacing plastic bags with their alternatives. Notably, the results of the BioPlastic scenario showed that 892 additional job places could be established, which is two-fold the second-best alternative of ConsReduction and four-fold of the PaperBags scenario.

While the socioeconomic impact analysis results indicated the positive contributions of the analysed alternatives to plastic bags, the results of the environmental impact assessment refined the results. They disclosed that the analysed strategies should be treated differently in relation to the impact on GHG emissions. Specifically, the outcomes of the scenarios showed that the production and use of paper bags and bioplastic bags result in increases in GHG emissions of up to 30 $ktCO_{2eq.}$, although due to the behavioural change towards the reduced consumption of plastic bags, decreases in GHG emissions are expected of up to 5 $ktCO_{2eq.}$.

Thus, the results of the comparative analysis of the socioeconomic and environmental impact assessment justifies the ConsReduction scenario, assuming economic growth, additional employment, and reductions in GHG emissions to be a priority in economic and climate policy making. This conclusion is also supported by the uncertainty analysis that included different weights for the impact areas. On the other hand, it must be stressed that all three scenarios show positive effects on GDP growth and employment, while their impact on GHG emissions is mixed. Given the fact that the reduction in plastic waste requires complex measures, it can be argued that the sustainability options examined can be part of a package of measures. However, in addition to action on plastic bags, it is necessary to address the reduction in GHG emissions in related branches of the economy.

Author Contributions: Conceptualisation, V.L., R.B. and D.K.; methodology, V.L., R.B. and K.R.; software, V.L.; validation, V.B. and J.V.; formal analysis, V.L., K.R., V.B., R.B. and J.V.; investigation, K.R., V.B., R.B. and J.V.; resources, V.L. and D.K.; data curation, V.L., V.B., R.B., K.R. and D.K.; writing—original draft preparation, V.L., V.B., R.B., K.R. and J.V.; writing—review and editing, D.K., V.B., R.B.; visualisation, V.L., R.B. and V.B.; supervision, V.L.; project administration, V.L.; funding acquisition, V.L. All authors have read and agreed to the published version of the manuscript.

Funding: This project has received funding from the Research Council of Lithuania (LMTLT), agreement No. S-MIP-20-53.

Data Availability Statement: The social accounting matrices used in this research can be openly accessed at https://doi.org/10.5281/zenodo.8195912. The dataset includes both the input data (Reference SAM) and the SAMs resulting from the scenario simulation.

Acknowledgments: The initial version of this study was presented at the 36th EBES Conference in Istanbul. The authors are grateful to the conference participants for their insights and suggestions.

Conflicts of Interest: The authors declare no conflict of interest.

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